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Characterization Of Intense Electron Beams Produced In Hollow Cathode Pulsed Discharges For X-Ray Generation.

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13. ABSTRACT (Maximum 200 words)

This report results from a contract tasking Institute of Physics and Technology of Radiation Devices as follows: The contractor will perform investigations in characterization of intense electron beams produced in hollow cathode pulsed discharges for X-Ray generation. She will summarize recent literature on advanced X-Ray sources based on pseu ark like discharges as well as capillary and inverse-capillary discharges. Develop devices for measuring parameters of the pulsed electron beam and characterized intense electron beams produced in pre-ionization controlled hollow ca pulsed discharges.

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Final Report

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Title of Research: CHARACTERIZATION OF INTENSE ELECTRON BEAMS PRODUCED IN HOLLOW CATHODE PULSED DISCHARGES FOR X-RAY GENERATION

Studies of pulsed electron beams are required in development of x-ray sources for triggering the energy stored in long-lived nuclear isomers [1].

In transient open ended hollow cathode discharges, controlled by a low current DC preionization discharge, intense pulsed electron beams are obtained [2, 3]. In this Final Report a complete characterisation of such electron beams extracted through an anodic bore hole is presented. For the characterisation of this pulsed electron beam a Faraday cup and a magnetic analyser were developed and presented in the Interim Report [4].

In order to obtain a X-ray source, the interaction between the electron beam and a target at 90 ° in the axial direction was studied. The X-ray emission was given by the beam's interaction with a 25μm Al foil mounted on the anode (fig.1). The measurements was performed on the radiation transmitted through the aluminium target. Due to the foil absorbtion, only radiation with energies higher than approx. 5 keV was measured. A X-ray pinhole was used to estimate the diameter of the fast electron beam. The pinhole

was made of Pb and had a conical shape, with a minimum diameter of approximatively 0.1 mm and 0.5 thickness.

Typical oscillograms of the applied voltage, discharge current and electron beam are presented in fig.2.

The current peak of the electron beam has a double structure, representing the convolution of two different peaks: the first one, which is simultaneous with the discontinuities observed at the beggining of the current rise and voltage fall, contains fast-electron component; the second one appears when the voltage is low and correspons to low-energy electrons. This was also confirmed by using a low variable magnetic field to deflect the electron beam before the entrance aperture of the magnetic analyser. We observed that the second peak was more strongly reduced than the first one for a fixed low magnetic field. The positive spike following the beam current, for a short time, was also observed in a single gap pseudospark. In the presence of the reversed discharge current discharge, for a short time, the Faraday cup plays the role of a hollow cathode until the discharge has been localized entirely on the anodic aperture. Even in the pseudospark multigap geometry in which the separation between the discharge and the drift space is relatively increased, such a positive spike in the beam current was observed [5].

A typical signal scintillator signal is given in fig.3. The FWHMs of the scintillator signals are practicaly the same (≤10ns) for electrons with energies higher than 4 keV (the lower limit of the magnetic analyser). This value of the temporal width of the beam is overestimated due to the scintillator (~2 ns), photomultiplier (~5 ns) and oscilloscope (~3 ns) time responses. Since the scintillator signals and the first peak of the beam current measured with the Faraday cup were simultaneous, we conclude that the second peak of the Faraday cup signals corresponded mainly to the electrons with energies less than 4 keV.

A typical time-integrated spectrum for 23 kV is given in fig. 4: the mean energy is approx 17.5 keV and the FWHM is about 7 keV.

X-ray short pulses are recorded by replacing the pinhole by a scintillator-photomultiplier-oscilloscope chain; the scintillator is dressed in a thin Al foil for protection against the light. A typical X-ray pulse is given in fig. 5a and, as had been expected, has a form quite similar to that of the scintillator signal from direct fast-electron measurements.

The pinhole image of the emission spot was recorded on the x-ray photographic film. In order to obtain a clear image of the spot, high exposure times for the film (up to 10,000 shots) were used. The exposure time was limited by the bore hole drilled in the Al target by the beam; for this reason the Al foil must be replaced after each exposure. The diameter of the X-ray emmision spot was in the range of 150-450 μm (fig. 5b) and the diameters of the drilled bore holes was in the same range.

Due to the long exposure times used for estimating the beam diameter, the measurements give simultaneously two different and inseparable kinds of information: about the electron beam diameter and aboutradial stability of the beam for several tens of thousands shots. The typical parameters of the electron beam are summarised in the Tabel 1, for a 23 kV applied voltage.

Tabel 1. Typical parameters of the electron beam

Mean electron energy (ME) (0.60-0.76 of maximum applied voltage)	17.5 keV
FWHM of energy spectrum (0.4 of ME)	7 keV
Temporal width of the fast electron beam	10 ns
Temporal width of the beam	14 ns
Integrated diameter of the x-ray emission spot	150-450 μm
Beam charge	1μC
Maximum beam current (aprox. 0.1 of the maximum current discharge)	65 A

Thus, the experimental setups presented in Interim Report and herein allow a complete characterisation of the electron beam in terms of: the electron beam current, the electron total charge, the quality of the beam collimation, the electron energy spectrum, the temporal width of the electron beam, and the diameter of the fast component of the electron beam [6].

FIGURE CAPTION

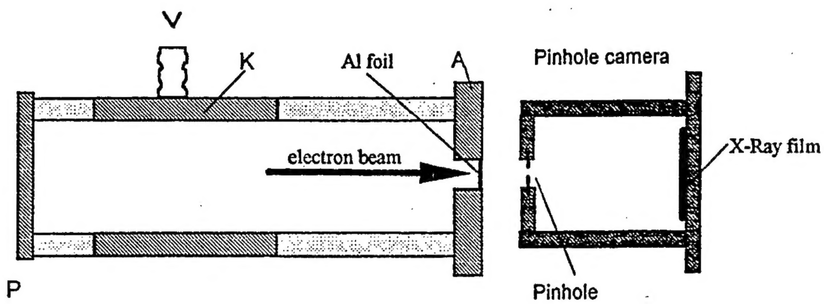


Fig.1 The experimental setup for x-ray pinhole measurements

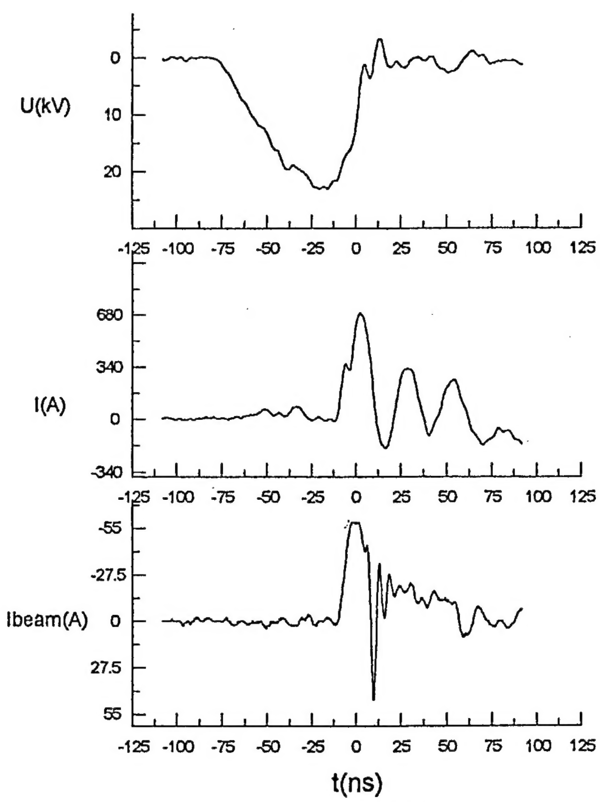


Fig.2 Typical oscillograms for the applied voltage, discharge current and electron beam current

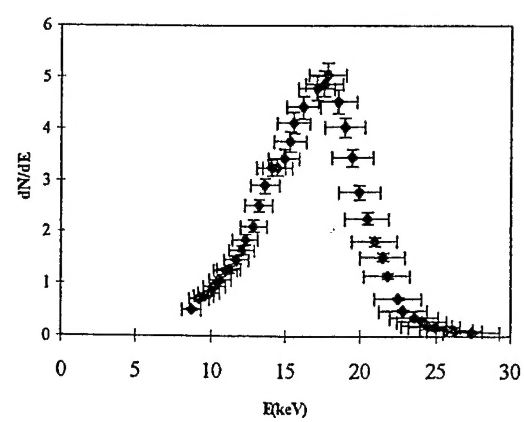


Fig.3 Energy spectrum for 23 kV breakdown voltage

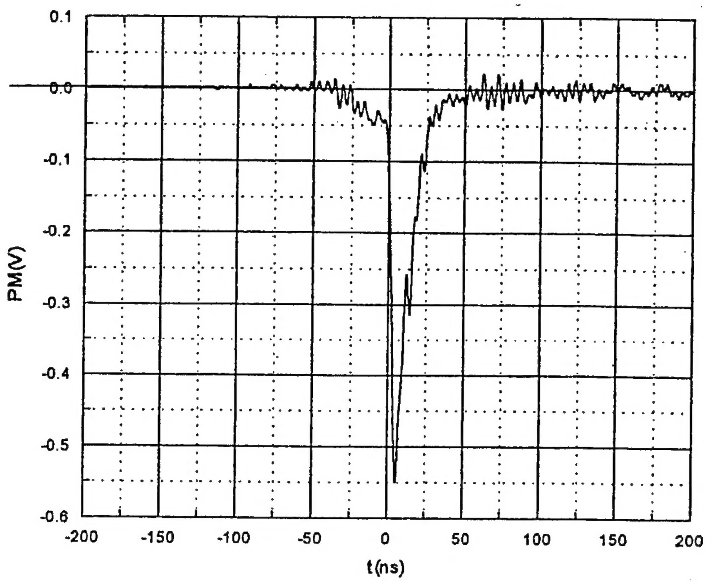
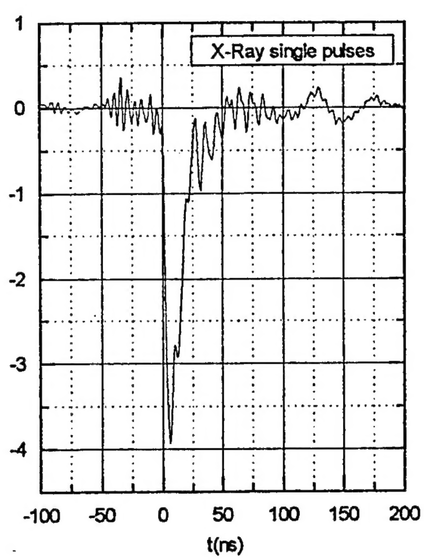
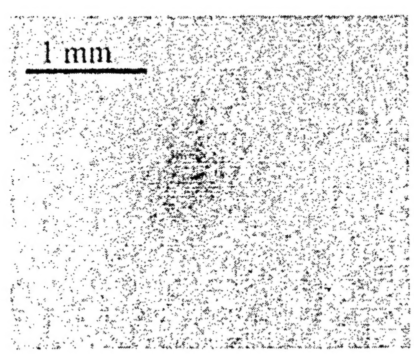


Fig.4 Typical scintillator signal for electrons with energy values in the range 11-12.5 keV



(a) single-pulse data;



(b) a pinhole picture.

Fig.5 X-ray measurements:

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